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ADVANCED LIGHT SOURCE

October 22, 1999

Memorandum

To: Zahid Hussain, Howard Padmore, Neville Smith

From: Michael C. Martin, Wayne R. McKinney

Subj: Far-IR Workshop Summary

On October 20, 1999 we convened a workshop to discuss the possibilities of a Far-IR source at the ALS, review the science that would benefit from such a source, and identify top scientists with the skills and interest to lead a drive to completion.

Just over thirty attended the workshop. Please refer to the attendee's list and the program schedule appended at the end of the memo.

• **Morning Session:**

Mike started off the program by briefly giving the reason for the workshop, and describing the current BL 1.4 complex for microscopy, timing, and surface science.

Next Bob Bosch, an accelerator physicist from SRC at the University of WI, described results from most of the IR facilities in the world calculated with the Synchrotron Radiation Workshop code written by Chubar of the ESRF. Bob has confirmed the accuracy of this code by his own calculations and measurements at SRC. He presented results comparing the sources in flux and brightness at each facility for bending magnet IR and for edge radiation IR. Generally, for all wavelengths the brightness of the two types of source is similar, providing no significant advantage of edge over bending magnet and vice-versa for brightness limited applications such as microscopy. For the Far IR region there can be approximately a factor of 10 in flux gained by the use of edge radiation. This is due to the fact that the edge radiation comes out in a cone of angle proportional to $1/\gamma$.

Ulrich Schade of BESSY II presented measured results from an edge source confirming the calculations done by Bosch. These measurements, however, do not yet extend into the Far-IR spectral region. He also presented plans for a new IR beamline at BESSY II.

To present one possibility for Far-IR at the ALS Wayne then presented calculations done with Bob Bosch's assistance which compared the 3 to 1000 micron flux and brightness of the current BL 1.4 front end, and a potential Far-IR port at the 1.0 injection straight port using edge radiation from the first sector one bending magnet. This has

several advantages. No other program wants the injection straight. There is plenty of room inside the tunnel at that point, and there should not be a significant heating problem from X-rays at the 1.0 port. Wayne's calculations confirmed the approximate order of magnitude increase in Far-IR flux over the 10 by 40 mr BL 1.4 port. It should be noted that the vertical opening of 1 inch at the 1.0 port starts to cut off the top and bottom of even the edge radiation beyond a wavelength of 100 microns (100 cm^{-1}).

John Byrd presented his ideas about the construction of a coherent Far-IR source that would be placed in the current booster tunnel. Prospective beamlines could use the space on the roof of the shielding. Since this shielding is a single pour the vibration problems seen on the removable shielding blocks of the ALS storage ring would not be as significant. This is an attractive idea that stimulated much discussion. Not only would it be an excellent Far-IR source, but the extremely short pulse lengths required for the coherent emission would enable new science based on the new fast timing capabilities. It would use a much smaller beam current that would reduce the complexity and costs. The drop in flux due to using a low beam current would be more than offset in the Far-IR by the coherent "n squared" emission. The much shorter electron bunches are attainable with modifications to the typical storage ring parameters, particularly increasing the RF voltage by using a superconducting RF cavity.

After a coffee break, Larry Carr of the NSLS presented a talk on the current status of the U12IR beamline and some of the Far-IR science they have been doing with it. After reviewing some classic high- T_c superconductor measurements done at Brookhaven, Larry reported on work that has been done using a synchronized pulsed laser system to look at fast dynamics in semiconductors and superconductors. It was pointed out that this type of pump-probe spectroscopy could be done with higher time resolution at the ALS where the electron bunches are ten times shorter than they are at the NSLS.

At this point Joe Orenstein took over as session chair as the workshop turned toward scientific applications of Far-IR. He challenged the next speakers to indicate what, if any, benefit to their respective scientific programs would accrue from the construction of a dedicated Far-IR beamline at the ALS.

Zack Schlesinger from UC Santa Cruz presented a very nice overview of Far-IR spectroscopy applied to the problems in strongly correlated electron systems, with an emphasis on some d-level electron materials. Even though his apparatus is state-of-the-art lab-based Far-IR, his measurements are extremely time consuming because of the inherent lack of signal in laboratory-based sources. He is very enthusiastic about the potential increase in signal from a Far-IR beamline, which would allow him to do a lot more measurements.

Dimitri Basov from UC San Diego continued this theme by presenting Far-IR reflectivity measurements from the c-axis of several high- T_c superconductors. The c-axis is always the smallest dimension in these planar materials so these experiments are brightness-limited. The analysis of his data showed that a spectral weight sum rule couldn't completely account for the superfluid density. His experiments also would benefit significantly from greater Far-IR brightness.

- **Afternoon Session:**

Following lunch, Mike and Wayne gave the group a tour of the current Beamline 1.4 IR complex. NSLS staff were particularly interested in the active feedback system for taking out microphonic motion of the light beam, and several attendees expressed interest in using the Mid-IR microscopy capability of BL 1.4.3.

Zack Schlesinger then chaired the afternoon session, which had descriptions of three less conventional uses of the Far-IR range:

Joe Orenstein of UC Berkeley and LBNL MSD presented some of the results he has obtained using his terahertz spectroscopy system, an alternative method for measuring in the very Far-IR wavelength range. With it he has been investigating the pseudo-gap region of the high- T_c superconductors' phase diagram. His present technique measures only up to approximately 30 cm^{-1} , and would benefit from overlapping Far-IR measurements on the same samples at the ALS.

Laszlo Mihaly, a solid state physicist from SUNY Stony Brook, followed by describing his new experimental setup which is being setup at one of Brookhaven's Far-IR beamlines. He is using a very high resolution FTIR bench, combined with a high-field superconducting magnet to enable measurements of Electron Spin Resonance (ESR) at higher frequencies than ever before. Indeed the new system will use the FTIR measurement process to obtain ESR results at a wide range of frequencies simultaneously. This will be an entirely new and very fast method of probing strongly interacting electron spins in a variety of systems.

Frank Keutsch, a graduate student standing in for Richard Saykally of the UC Berkeley Chemistry Department presented the final talk of the day. He described their labor-intensive efforts to measure the absorption of gaseous water clusters in the Far-IR at incredibly high-resolution. Their IR source is very tricky to maintain, but seems to be the only current method of producing such high-resolution measurements. A Far-IR source at the ALS could potentially provide considerably more flux for their experiments, but it is not clear if it is possible to make an FT or dispersive instrument that has as much spectral resolution as their laser plus microwave non-linear beating technique.

- **Discussion:**

At the end of the presentations, Mike thanked everyone for participating and opened the workshop to a round-table type discussion. The entire group stayed until nearly 5pm going over several issues of the day. We were very pleased that the overall tone of all those in attendance was enthusiastic for the construction of some kind of Far-IR facility at the ALS. The potential science that could be enhanced by such a facility was deemed very worthwhile and the value of having a West Coast Far-IR synchrotron facility was highlighted.

Some concern was expressed that the edge radiation has not been observed sufficiently in the Far-IR. In the case of NSLS, the lack of Far-IR observed to date is explained by Bosch as the natural cutoff of the radiation as the cone becomes bigger than the aperture in the ring. In addition the possible interaction of the vacuum chamber with the longer wavelength radiation must be considered. More careful experiments are needed to fully evaluate the potential of edge radiation as a Far-IR source.

Some considered the most straightforward method to get more Far-IR is to open up a port in the ring allowing collection of the longer wavelengths that have a much larger opening. The group encouraged us to investigate the costs involved with changing the chamber in both the bending magnet and edge radiation cases.

- **Conclusions:**

The overall conclusions and recommendations of the workshop are:

- A dedicated Far-IR beamline should be built at the ALS.
- Dimitri Basov and Zack Schlesinger emerged as the most enthusiastic potential users of Far-IR at the ALS, eager to help find the support for such a facility and help guide in the selection of scientific apparatus for end-stations. Joe Orenstein is also interested and willing to help.
- The ALS staff should determine the cost to modify a sector chamber to allow a larger vertical collection angle for standard beamline ports as well as for the existing "IR ports" where being closer to the bending magnet is advantageous. Continue calculations and estimates for using the injection straight for edge-radiation. This would identify the most cost-effective means of getting Far-IR out of the ALS ring. For the future, get a first pass at a cost estimate for Byrd's coherent Far-IR ring proposal.
- Once the technical details for extracting Far-IR from the ALS ring are pinned down, a full proposal should be written to fund and build a new Far-IR facility.

List of Attendees:

Joe Orenstein	University of CA, Berkeley
Eugene Haller	University of CA, Berkeley
Zack Schlesinger	University of CA, Santa Cruz
Paul Richards	University of CA, Berkeley
Dimitri Basov	University of CA, San Diego
Gwyn Williams	NSLS, Brookhaven National Lab
Larry Carr	NSLS, Brookhaven National Lab
Bob Bosch	SRC, University of Wisconsin
Ulrich Schade	BESSY II
Angela Hight-Walker	National Institute of Standards and Technology
Laszlo Mihaly	State Univ. of NY at Stony Brook
John Byrd	LBNL Accelerator Physics
Dave Robin	LBNL Accelerator Physics
Jeff Hesler	University of Virginia
Chris Weber	University of CA, Berkeley
Emil Hallin	Canadian Light Source
James Chesko	ALZA Corporation
Steve Irick	LBNL
Frank Keutsch	University of CA, Berkeley
Kevin Wilson	University of CA, Berkeley
Satish Myneni	Princeton University and LBNL
Phil Huie	Stanford University, Dept. of Pathology
Todd Smith	Stanford University Hansen Laboratory IR FEL
Hoi-Ying Holman	LBNL LSD
Phil Ross	LBNL MSD
Birgit Schwickert	University of CA, Berkeley
Donna Hamamoto	LBNL ALS
Cheryl Hauck	LBNL ALS
Joel Ager	LBNL MSD
Sherry Zhang	LBNL EEAET
<i>Organizers:</i>	
Michael C. Martin	LBNL ALS
Wayne R. McKinney	LBNL ALS

Far-IR Workshop Program

1999 ALS Users' Meeting
October 20, 1999

Wednesday October 20

- 8:30 *Continental
Breakfast*
- 9:00 Michael Martin Welcome
 ALS

Far-IR Synchrotron Beamline Sources

Chair: M. Martin

- 9:10 Bob Bosch "Edge radiation as a source for an IR beamline"
 SRC, Wisconsin
- 9:40 Ulrich Schade "IRIS: An IR-beamline at BESSY II"
 ISAS, Berlin
- Wayne
- 9:55 McKinney "Specific Source Considerations for Far-IR at the ALS"
 ALS
- 10:10 John Byrd "A Coherent Far-IR Synchrotron Source in the ALS Booster
 ALS Tunnel"
- 10:40 *Coffee Break*
- 11:00 Larry Carr "The NSLS U12IR far infrared beamline, scientific programs and
 NSLS, BNL results"

Far-IR Science

Chair: J. Orenstein

- 11:30 Zack Schlesinger "Infrared studies of strongly correlated electron systems"
 UC Santa Cruz
- 12:00 Dimitri Basov "An Infrared Probe of the Energetics of Superconducting State in
 UC San Diego High-T_c Cuprates"
- 12:30 *Lunch (provided for registrants)*
- 1:30 Tour of ALS IR Beamlines

Far-IR Science (continued)

Chair: Z. Schlesinger

- 2:00 Joseph Orenstein "Terahertz spectroscopy of copper-oxide superconductors"
 UC Berkeley
- 2:30 Laszlo Mihaly "Electron Spin Resonance on Strongly Interacting Spins: a Novel
 SUNY Stony Far-IR Application"
 Brook
- 3:00 Richard Saykally "Far-IR Laser spectroscopy of Water Clusters"
 UC Berkeley
- 3:30 *Coffee Break and Discussion*